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Anomalous Increase of Lyman Alpha Flux During the Solar Maximum Phase of Cycle 21 Observed by the AE-E Satellite

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16 January 1990

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13. ABSTRACT (Maximum 200 words)

Observational data of EUV fluxes made by the AE-E satellite during the active phase of solar cycle 21 were published by Hinteregger et all as a file named SC#210BS. Among emission lines listed in this file, H. Lyman alpha showed a somewhat unexpected increase during the solar maximum phase starting the first month of 1979. Several authors such as Bossy, Lean and Skumanich, and Oster who studied the variability of EUV fluxes through their models failed to explain this anomalous increase, and concluded that the calibration of the data must be in error.

This paper presents the result of a careful examination of the AE-E data from the designer and the operator's point of view and tries to draw possible conclusions as to the reliability of the data. Also the data themselves were analyzed and compared with solar indices to find out if this increase is a solar related phenomenon or merely due to an instrumental artifact.

The analysis seems to indicate that the increase is indeed real because: (1) two independent detectors, MN 22 and MN 8, recorded nearly identical results for the Lyman alpha irradiance; (2) such an increase has also been observed for the Lyman beta, HeI and FeIX irradiances for the same period though somewhat reduced in scale; (3) sensitivity degradation of detectors is rather common, but increases occur under special conditions, such as the decrease of opacity of the filter (continued)

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or the shift of the sensitivity curves of the detectors, and they can be safely eliminated in this case, (4) short term variabilities of observed EUV fluxes are in good agreement with those of solar indices assuring that the detectors are all in normal operating conditions; and (5) the increase period of the EUV fluxes coincides almost exactly with the most active phase of solar activity subsided to a certain level.

The anomalous increase of Lyman alpha may thus be the result of a secondary production mechanism of the flux which was triggered by the solar activity when it reached a certain level at the beginning of 1979.

Preface

The author wishes to thank H. E. Hinteregger for his advice and encouragement on this report.

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Anomalous Increase of Lyman Alpha Flux During the Solar Maximum Phase of Cycle 21 Observed by the AE-E Satellite

1. INTRODUCTION

The AE-E satellite carrying the solar extreme ultraviolet spectro-photometer (EUVS) was launched in November 1975, and about one month later, on 22 December, the detectors were turned on and the first data were obtained. Until the satellite was terminated in June 1981, a large amount of valuable EUV data were collected from the continuous observation, which lasted over 5 years. When this satellite was launched, solar cycle 20 was about to end and the solar minimum was observed six months later (June 1976) starting a new cycle 21. Unfortunately, some of the monochromators were not stabilized until April 1977 and reliable data were available only after July 1977. These data were carefully calibrated and published as a file named SC#210BS[1] which contains the relative flux values of 15 wavelength groups including Lyman alpha, Lyman beta, HeI, HeII, FeIX, and FeXVI for the period of 77182-81160. All of the flux values are given as the ratios to the values observed during the so called reference period 76195-76210 when the solar activity was near minimum[2].

(Received for Publication 16 January 1990)

[1] Hinteregger, H.E., Fukui, K., and Gilson, B.R. (1981) Observation reference and model data on solar EUV, from measurement on AE-E, *Geophys. Res. Lett.*, **8**(No. 11):1147-1150.

[2] Hinteregger, H.E. (1981) Solar irradiance and its variations at wavelengths below 185 nanometer, Middle Atmosphere Symposium at the IAGA Edinburgh Assembly, Session 2M (e).

The significance of this analysis is that the period of observation covers the rising and maximum phases of solar activity in cycle 21. Thus, the data provided excellent material to study the long-term behavior of EUV fluxes with respect to the solar activity.

Figure 1 shows a plot of 81-day sliding averages of AE-E observed solar chromospheric lines in logarithmic scale. They are: Lyman beta (1), HeI (2), HeII (3) and Lyman alpha (4) for the entire observation period of AE-E. Also, 81-day sliding averages of the F10.7 index (5) were added for comparison. The most striking feature of this result is that Lyman beta, HeI and HeII are nearly identical, whereas Lyman alpha shows a sharp increase during the maximum phase, but gradually subsides to the level equivalent to other chromospheric lines during the post-maximum phase. Several authors, such as Bossy[3], Lean and Skumanich[4], and Oster[5],

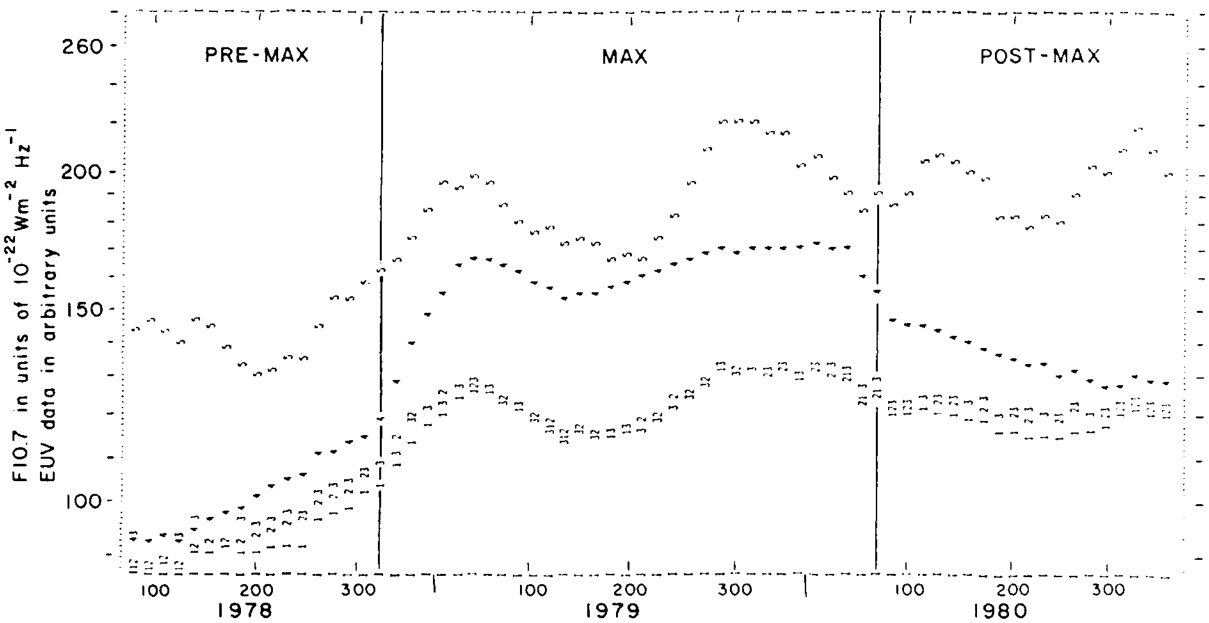

Figure 1. An 81-Day Sliding Average of Four EUV Fluxes: HeI 584 Å for MN5 (1), HeII 304 Å from MN2 (2), Lyman Beta From MN9 (3), and Lyman Alpha From MN 22 (4), as Well as One Solar Index F10.7 (5). Data from every 15 days (78080-80355) are plotted on a logarithmic scale in arbitrary units to make comparison easier by shifting the heights. Three fluxes, HeI, HeII, and Lyman beta, show an excellent agreement among themselves, while Lyman alpha showed a large increase during the maximum phase but returned to the original level. F10.7 was added for comparison. 81-day average was taken to eliminate 27-day cycles safely.

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3 Bossy, L. (1983) Solar indices and solar UV irradiances, *Planet Space Sci.*, **31**:977-985.

4 Lean, J.L., and Skumanich, A. (1983) Variability of the Lyman alpha flux with solar activity, *J. Geophys. Res.*, **88**(No. A7):5751-5759.

5 Oster, L. (1983) Solar irradiance variations, 2. Analysis of the extreme ultraviolet measurements onboard the Atmosphere Explorer E satellite, *J. Geophys. Res.*, **88**(No. 411): 9037-9052.

pointed out that the Lyman alpha flux during the solar maximum phase was too high and the calibration applied was not correct.

2. AE-E DATA

Some of the previously published materials[6, 7] concerning the data reduction are briefly reviewed in this section to clarify the circumstances in which all the data were obtained. It should be emphasized that although all the detectors were carried by the same vehicle, the data, with certain characteristics such as short-term variabilities, as well as sudden increases, were obtained from different monochromators independently, and the agreement among them cannot be explained as instrument-related phenomena; yet, each detector covered the entire period of the observation demonstrating that phenomena such as an anomalous increase are not combined products of two or more different detectors.

As described below, some of the monochromators needed time to settle down, and only then were reliable results obtained. In this analysis, data produced before the settlement were carefully avoided.

2.1 Instrumentation

The AE-E satellite carried 24 monochromators, designated MN 1-MN 24. Among them, MN 1-MN 12 were scan-monochromators and MN 13-MN 24 were fixed wavelength monochromators. MN 1-7, 9, and 10 were all equipped with independent open CEM (channel-electron multiplier) detectors and gratings with full disk FOV for the observation of the fluxes of wavelength less than 1200 Å. They had relatively minor problems after the running-in period, one-half year from the first exposure.

The Lyman beta (1026 Å) flux was obtained from MN 9 (918-1049 Å, $\Delta\lambda \cong 2.3$ Å) but it was also obtained from MN 6 (989-1192 Å, $\Delta\lambda \cong 7$ Å), and the sets of data were checked one against another. HeI (584 Å) flux was obtained from the weighted mean values taken by MN 5 (516-653 Å, $\Delta\lambda \cong 10$ Å) and second-order diffraction by MN 6 (986-1192 Å, $\Delta\lambda \cong 7.6$ Å, that is, $\Delta\lambda \cong 3.5$ Å for 2×584 Å). No correction for this flux was needed for the entire observation period after July 1977.

MN 11 (full-disk FOV, 1230-1370 Å), and MN 12 (6' × 6' FOV, 1370-1850 Å) were both equipped with sealed off PMT detectors and MgF_2 filters.

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[6] Hinteregger, H.E., Bedo, D.E., and Manson, J.E. (1973) The EUV spectrophotometer on Atmosphere Explorer, *Radio Science*, **8**(No. 4):349-359.

[7] Hinteregger, H.E. (1980) AE-E experiences of irradiance monitoring for 1200-1850 Å, in *Proceedings of Workshop on Solar UV Monitoring* held 31 July -1 August 1980 in Boulder, Colorado, pp. 9-25.

Two monochromators, MN 21 and MN 22, were specifically designed for the observation of the Lyman alpha flux with open structure CEM detectors and MgF_2 filters, but the former was equipped with a small opening of 6' × 6' FOV, less convenient for the long term variability study of the flux, while the latter was equipped with a full-disk FOV and provided the most important data for the study of the long term variability of the Lyman alpha flux. The wavelength was fixed at 1216 ± 50 Å.

MN 8 was originally designed for the observation of the longer wavelengths. This was a scanning monochromator for 1250-1700 Å with $\Delta\lambda \cong 25$ Å with a full FOV, but it was found that the flux data for wavelengths longer than 1350 Å consist almost totally of the scattered light of the Lyman alpha radiations. The result will provide excellent alternative data for the Lyman alpha flux, as will be discussed later in detail.

Twelve monochromators, MN 1-MN 11 as well as MN 22, were designed for the observation of the entire solar disk with a square field-of-view of 60' × 60', whereas the diameter of the solar disk is only 32' allowing a pointing fluctuation of as much as the radius of the sun.

All 24 monochromators were mounted together as one solid block onto the satellite, and no relative movement among the monochromators was possible. If there were pointing irregularity it would affect in the same way all those monochromators with the same field-of-view, such as MN 22 and MN 8. However, n irregularity of pointing factors has been recorded during the entire mission of the AE-E satellite, and data indicated that no substantial pointing problem occurred.

This means that two of the Lyman alpha observing monochromators, as well as the monochromators observing other chromospheric lines such as HeI, HeII, and Lyman beta were always pointing exactly in the same direction covering the entire solar disk. Thus, there is no reason to believe Lyman alpha values differ from other chromospheric lines due to pointing irregularity.

2.2 Degradation

As shown in Figure 2, a very sharp degradation started immediately after the launch for both MN 22 and MN 8, and it lasted for several months until July 1976, then the degradation slowed down to the level of an essentially smooth curve of decaying instrumental sensitivity. They eventually settled down by June 1977, one year after the solar minimum.

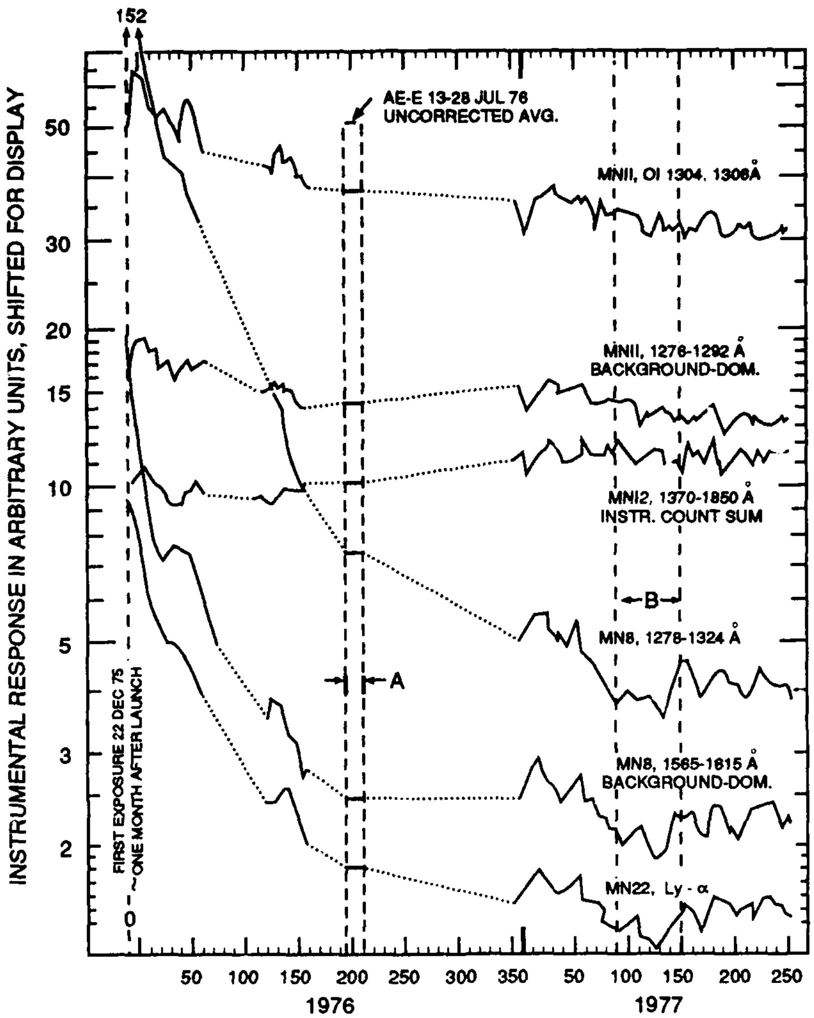

Figure 2. This Figure Shows the Sensitivity Degradation During the Running-in Period. Fluxes observed by PMT detectors (MN 11, MN 12) need little correction, but CEM detectors lost sensitivity substantially until July 1976 (period "A"), then further degradation seemed to have occurred for MN 22 and the shorter wavelength portion of MN 8 till the period "B". At this point all MN settled down, and the data after July 1977 are considered reliable[7].

In order to explain these degradations, the factors that control the instrumental sensitivity for the measurement of Lyman alpha fluxes should be analyzed. There are seven independent factors: (1) the aperture area, (2) the instrumental spectral window function, (3) the count accumulation time, (4) the photoelectron counting efficiency of the CEM and associated circuitry, (5) the grating efficiency, (6) the photoelectric yield of the CEM detector, and (7) the transmission of the MfF_2 window. The aperture area and the instrumental spectral window function are geometrical factors. The count accumulation time is equal to 0.35 sec for each 0.5 sec for MN 22. These three factors are unchanged constants.

The photoelectron counting efficiency of the CEM and associated circuitry is constant if the counting is made in the plateau of the counting characteristic. The HV level was changed from 3 to 4 on 24 December 1976 (and stayed at 4 thereafter), but both MN 22 and MN 8 were operated essentially in the plateau both before and after this date, including the reference period of July 1976, and the deviation was with within 1-2 percent.

Various laboratory experiences showed that gold-coated diffraction grating used with grazing angles of incidence shows remarkably stable efficiencies. The same type of gratings used in the other grazing incidence monochromators of the AE-E instrument shows excellent long term stability. Based on these two experimental results, it can be assumed that the amount of change in the grating efficiency is extremely small[8].

Thus, the above five factors are practically constant, and they do not contribute to the drastic degradations.

The change in the photoelectric yield of the CEM detector must be considered as the possible sources of the degradation. The type of open CEM detectors were used quite successfully for the observation of the shorter wavelengths, where the photoelectric yield was around 10 percent. The yield for Lyman alpha is much lower, by a factor of about 10, because the energy of the Lyman alpha protons just barely exceeds the photoelectric work function. The Lyman alpha operating point falls on the declining part of the yield curve towards the longer wavelengths. This means that relatively small changes of surface conditions, and correspondingly small changes in the work function, can result in substantial changes in the yield. When the surface of the CEM detector was exposed to vacuum during the first phase of the exposure in orbit, the cleaning process of the surface began by ejecting the impurities on the surface which were responsible for the extra photoelectrons. As this process of cleaning progressed, the yield function gradually stabilized to the point that the nearly perfect outermost layer of the detector alone produced photoelectrons, creating a condition of no further change in the photoelectron yield. This can explain why such a drastic degradation occurred at the beginning, but gradually settled down. It also explains why MN 22 and MN 8 had somewhat different degradation rates for the first one-half year.

The only remaining factor still in question is the changes in the transmission of the MgF_2 window. Experiences from both laboratory studies and space experiments have indicated that the Lyman alpha transmission of MgF_2 window is indeed susceptible to some degradation depending on the environment. Although MN 22 and MN 8 are two independent monochromators, they used MgF_2 filters cut from the same crystal, and both faced the same environment; thus, the history of aging effects should also be nearly the same for both. It is therefore possible that small secondary degradation seen in Figure 2 could be due to the simultaneous aging of two filters.

It should be emphasized, however, that this effect only decreases the sensitivity of the instrument slightly, and any anomalous increase such as the Lyman alpha fluxes discussed in the report can be safely ruled out as the result of the aging effect of the MgF_2 crystals.

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[8] Hinteregger, H.E. (1987) Private communication.

2.3 Calibration

No correction due to the degradation is needed for the Lyman beta and HeI for the period between the reference period and October 1977. The absolute fluxes may then be calculated from the values in the reference spectrum. For example, the observed ratios of October 1977/ July 1976 for Lyman beta and HeI are 1.57 and 1.43 respectively. On the other hand, this ratio for the Lyman alpha is 0.855 indicating a decline of either the flux value itself or the instrumental sensitivity or both. Hinteregger[7] stated that the sensitivity decline is responsible for this value, and estimated the solar Lyman alpha value in July 1976 (reference period) is 35-60 percent below the observed value of October 1977 concluding the decline of the sensitivity by 42-77 percent. Then he assumes (1) there was no degradation of instrumental sensitivity for the entire period from July 1977 onward, (2) this stabilized sensitivity was 35 percent below the July 1976 sensitivity.

The absolute flux value of Lyman alpha for the reference period was published in R76REF[2] as 3.0×10^{11}ph/cm^2 sec. This value is in good agreement with 2.95×10^{11}ph/cm^2 sec, the average of two LASP data from No. 3 and No. 4 of that series[9], although the difference between the two is substantial (ratio: 1.68). On the other hand, the average of LASP No. 4 and No. 5 is 3.99, considerably higher than the reference value mentioned above. Uncertainty of LASP data is probably too large to allow any meaningful comparison, although these discrepancies are within the reasonable range.

In the file SC#210BS, most of the data obtained during the degradation period are eliminated rather than corrected, and only data after July 1, 1977 are listed. The Lyman alpha data before October 1977 listed in this file are corrected under the assumption that MN 22 did not stabilize until that time.

An AFGL rocket experiment on April 23, 1974 produced a value of 2.5×10^{11} ph/cm^2 sec, which is listed in a file named R7413[10]. The value listed in the reference spectrum is 17 percent higher than this value. This adjustment is based on the fact that the HeI 584 Å irradiance observed by AE-C went through a minimum around 10 April 1975 suggesting a rise in the quiet-disk radiance from cycle 20 to cycle 21. The above Lyman alpha flux value is in good agreement with OSO-5 results[11].

The important characteristic of calibration is, as shown here, to correct relatively long-term gradual decreases due to sensitivity change. It is rather unlikely to deal with short-term changes, periodic changes, or sudden increases or decreases of sensitivity.

According to the model calculations by Lean and Skumanich[4], the above Lyman alpha values should be lowered by 39 percent. However, this modification will have relatively little

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[9] Rottman, G.J. (1981) Rocket measurements of the solar irradiance during solar minimum 1972-1977, *J. Geophys. Res.* **86**(No. A8):6697-6705.

[10] Heroux, L. and Hinteregger, H.E. (1978) Aeronomical reference spectrum for solar UV below 2000 Å, *J. Geophys. Res.*, **83**:5305-5308.

[11] Vidal-Madjar, A. and Phissamay, B. (1980) The solar Lyman alpha flux near solar minimum, *Solar Physics*, **66**:259-271.

impact on the overall analysis of the anomalous increase of Lyman alpha flux discussed here, because the increase started at the beginning of 1979 when the detectors had already stabilized.

Bossy[3] stated that the irregularity of the Lyman alpha flux observed by AE-E, such as the sudden increase at the beginning of 1979, is due to instrumental effect, and preceded in his analysis based on the assumption that the solar index F10.7 and the Lyman alpha irradiance have a constant relationship. He assumed that the data were produced by two different parts of the equipment before and after January 1979, and he arbitrarily separated the data into two groups. This is a misunderstanding, and the data were in fact produced by the very same instrument and under the same conditions.

Oster[5] took a similar stand and decided all the abnormality of the Lyman alpha data is due to instrumental artifacts. He plotted Lyman alpha data against the Lyman beta data, and pointed out any departure of the Lyman alpha data from the linear relation between the two must be due to calibration error, because "there is nowhere a change in the solar behavior as seen in F10.7 during this time period." Then he excluded any possibility that the long-term variability of Lyman alpha is not necessarily the same as that of F10.7 and even other EUV fluxes.

A similar situation existed for the handling of this increase by Bossy and Nicolet[12] whose theoretical analysis proceeds under the assumption that Lyman alpha flux can be approximated by the use of F10.7 intensity alone.

3. ANALYSIS AND DISCUSSION

The following analysis of the data and the discussion provide enough evidence to demonstrate that the anomalous increase of Lyman alpha is not likely due to instrumental artifacts or calibration error.

3.1 Monochromators MN 22 and MN 8 for the Lyman Alpha Observation

As mentioned before, non-scanning MN 22 was designed to observe Lyman alpha with an open CEM detector with full disk FOV and an MgF_2 filter. The result was published in the file SC#210BS, but it became the target of the critics for the reliability of the AE-E data. However, there has been little discussion of the data from the scanning monochromator MN 8 which was also equipped with a full disk FOV open CEM detector. The two monochromators used instrumentally-independent CEM detectors, gratings, and MgF_2 filters. MN 22 and MN 8 belonged to different modules, and the HV supplies were independent, but all the HV of the CEM detectors including MN 22 and MN 8 were changed from level 3 to 4 on 24 December 1976

[12] Bossy, L. and Nicolet, M. (1981) On the variability of Lyman alpha with solar activity, *Planet. Space Sci.*, **29**(No. 8):907-914.

to operate them in the plateau. Moreover, they used two different principles of operation; one measured directly and the other measured the scattered light background. The characteristics of the CEM sensitivity curve belonging to MN 8 were well known from the pre-launch laboratory experiment. It was found that the real signals beyond 1350 Å were getting increasingly small and the reading was practically speaking zero above 1400 Å. When a small amount of radiation with shorter wavelength such as Lyman alpha was introduced, the detector recorded nothing but this extra radiation as the background. That is, the photoelectric yield of MN 8 for the wavelengths longer than 1350 Å turned out to be extremely small and scattered light background dominated the signals, which consisted almost completely of the Lyman alpha flux. MN 8 was originally designed to scan as far as 1700 Å, but it was decided to leave it in as scheduled, because eliminating or modifying this detector was no longer possible at the time of the assembly; it was extraordinarily lucky that the additional Lyman alpha data were obtained in this way. The flux in the wavelength range 1582-1596 Å observed by MN 8 is listed in the file[13] and is considered to represent the alternative Lyman alpha flux.

Daily values of the Lyman alpha obtained by MN 22 (middle curve) and MN 8 (x) are plotted in Figure 3 on an arbitrary logarithmic scale together with F10.7 data taken from the Solar Geophysical Data Comprehensive Reports (top curve) and the Lyman beta flux obtained by MN 9 (bottom curve) for the anomalous and the recovering period.

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[13] Fukui, K. (1989) Summary of AE-E observation on solar EUV-fluxes, to be published.

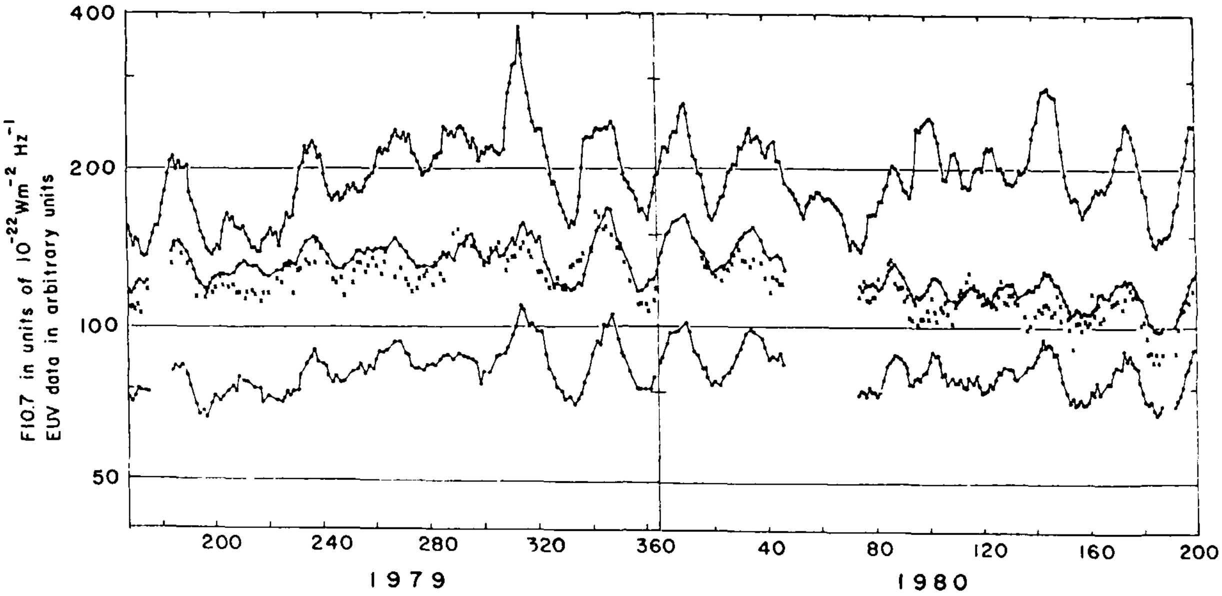

Figure 3. Logarithmic Plotting of Daily Values for the Transition Period From the Maximum Phase to the Post Maximum Phase. Three curves represent, from top to bottom, F10.7 (absolute unit), Lyman alpha by MN 22, and Lyman beta (arbitrary unit). Lyman alpha values observed by MN 8 are indicated by x. Note: (1) an excellent agreement is seen between two sets of Lyman alpha fluxes observed by MN 22 and MN 8, (2) both Lyman alpha fluxes showed a clear decrease after the maximum phase compared with F10.7 and Lyman beta, (3) short term variations of all the fluxes are in good agreement indicating all the detectors were operating normally.

The two independently observed Lyman alpha fluxes are in good agreement, and both of them show substantial decreases compared with the F10.7 flux level after 80090 when the anomalous period came to an end. A similar tendency is observed with respect to the level of the Lyman beta flux. Short term periodic variations of all four curves are in excellent agreement indicating trouble-free operations of the monochromators.

Figure 4 shows a plot of every five days of the Lyman alpha fluxes observed by MN 22 (o) and MN (x) during the entire period of the AE-E observation. An excellent agreement between two sets of data is seen throughout the period confirming the anomalous increase for the period as well as the magnitude. The two sets of data again showed good agreement during the termination phase when the satellite altitude lowered as it approached reentry and the thicker atmosphere gradually reduced the intensity of the Lyman alpha flux.

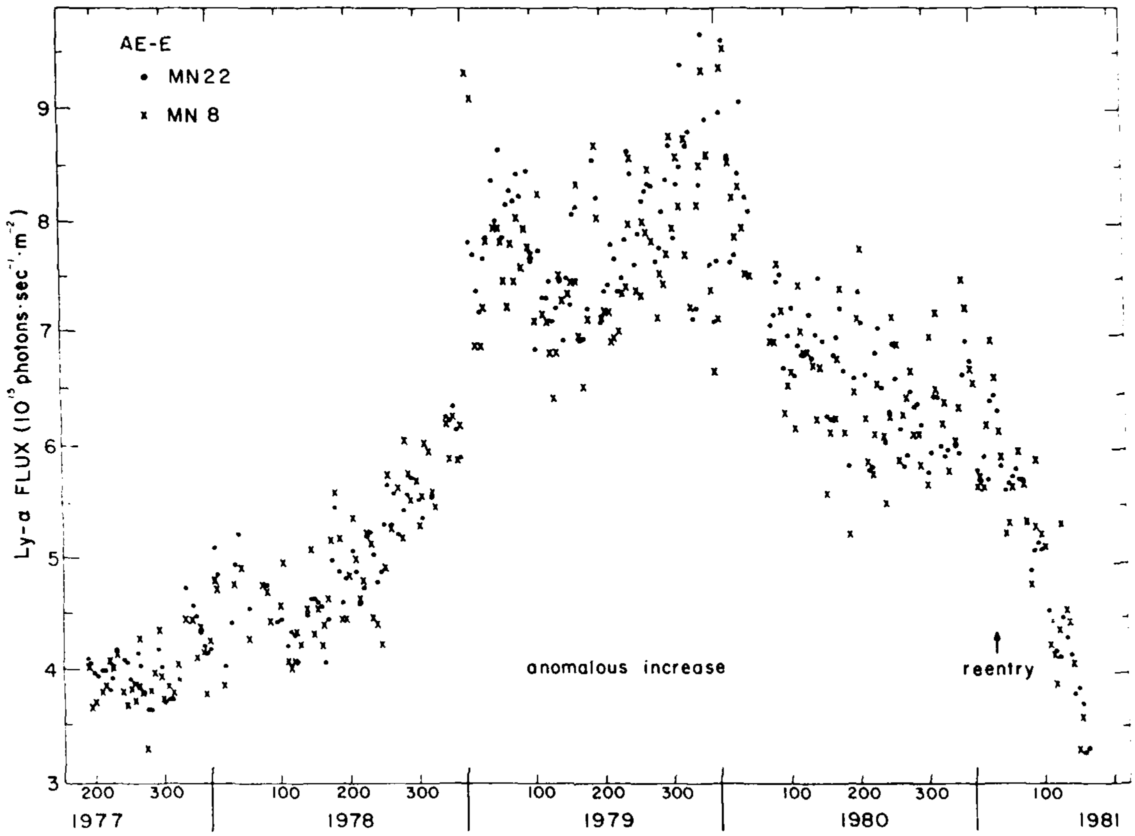

Figure 4. Lyman Alpha Data Observed by MN 22 (o) and MN 8 (x) Plotted on a Logarithmic Scale. The flux unit was taken from the file SC#210BS for MN 22, but the data by MN 8 were adjusted accordingly. Note that the anomalous increase of Lyman alpha was observed by both monochromators which are in excellent agreement. Note also that the two sets of fluxes showed very similar decreases when the satellite entered the termination phase.

The unit shown here is taken from the Hinteregger's criterion[2] for the values by MN 22 and the values from MN 8 are adjusted by multiplying them an appropriate factor.

To show the correlation, the Lyman alpha data from MN 22 and MN 9 are plotted against corresponding F10.7 values Figures 5a and 5b, respectively. In this diagram, Hinteregger's version[2] was revised by adding more data in the final phase. In either case, the data from the periods 77155-78365 (solid circles) together with 80095-81035 (open circles) form a reasonably good linear relation, whereas the data from the anomalous period 79005-80090 (crosses) form a separate group, indicating that the Lyman alpha flux increased disproportionately with respect to F10.7 during this period.

CORRELATION BETWEEN LYMAN ALPHA AND F10.7
(revised)

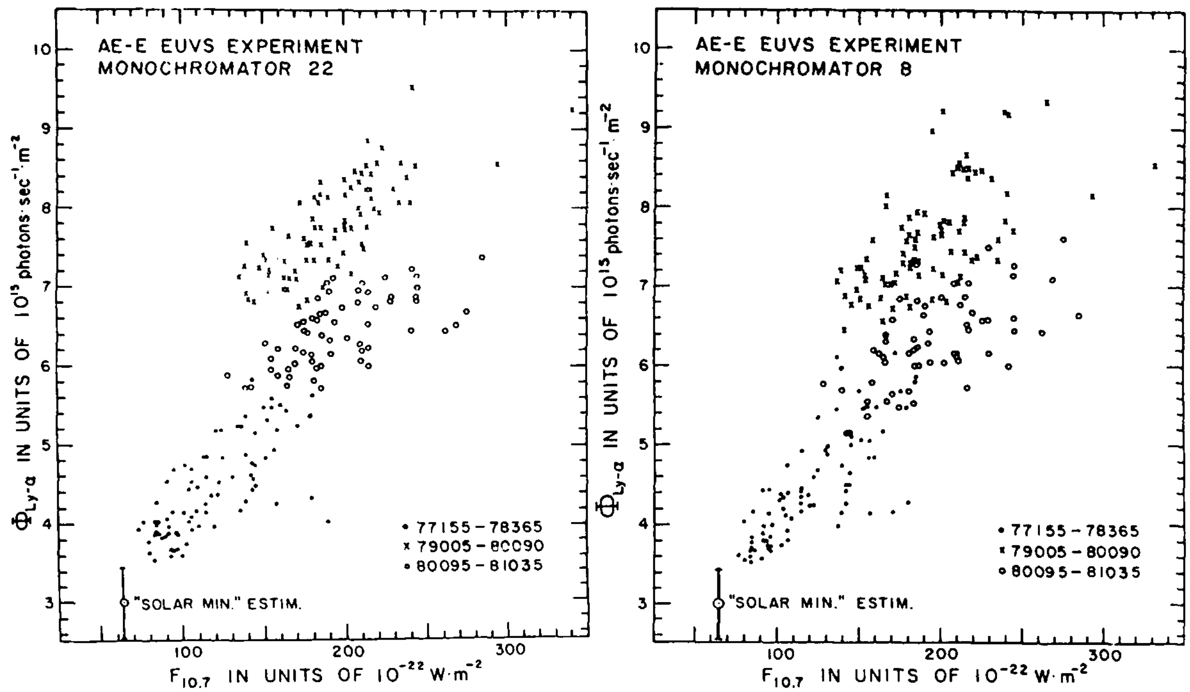

Figure 5. Correlation Plotting F10.7 Versus Lyman Alpha Flux by MN 22 (5a), and MN 8 (5b). The anomalous increase of Lyman alpha for the period of 79005-80090 can be clearly seen in both diagrams. The rest of the plots form a near linear relation between them. This figure is a revised version of Hinteregger[1] by adding the data up to 81035.

If we exclude the anomalous period, the flux of each EUV may be approximated by a linear relation

$$y = ax + b, \tag{1}$$

where x is the F10.7 flux, and y is the calculated EUV value. The factors a and b were calculated by the least squares method from the data of the nonanomalous period. They are listed in Table 1. The Lyman alpha values were then estimated from the F10.7 values for any given date. The deviations of the observed Lyman alpha values from the estimated values were plotted in Figure 6(a). The average of the calculated flux, the observed flux and the amount of the anomalous increase are given in Table 1, and the increase rate for the Lyman alpha flux was found to be as much as 41.5 percent.

Table 1. Anomalous Increase Rates for Various Fluxes

	Lyman alpha (MN 22)	Lyman beta	HeI	FeIX
Factor a[†] Factor b[†]	0.00729 0.70569	0.00891 0.80270	0.00940 0.77784	0.00466 0.78529
Calculated flux* for the anomalous period	1.250	1.388	1.072	0.708
Observed flux* for the anomalous period	1.769	1.615	1.250	0.811
Difference*	0.519	0.227	0.178	0.103
Observed increase in percent	41.5	16.3	16.3	14.5

† Two factors for the linear equation, and the calculated flux, the observed flux and the amount of increase for the anomalous period.

* The flux unit is the "relative unit" appearing in the file SC#210BS.

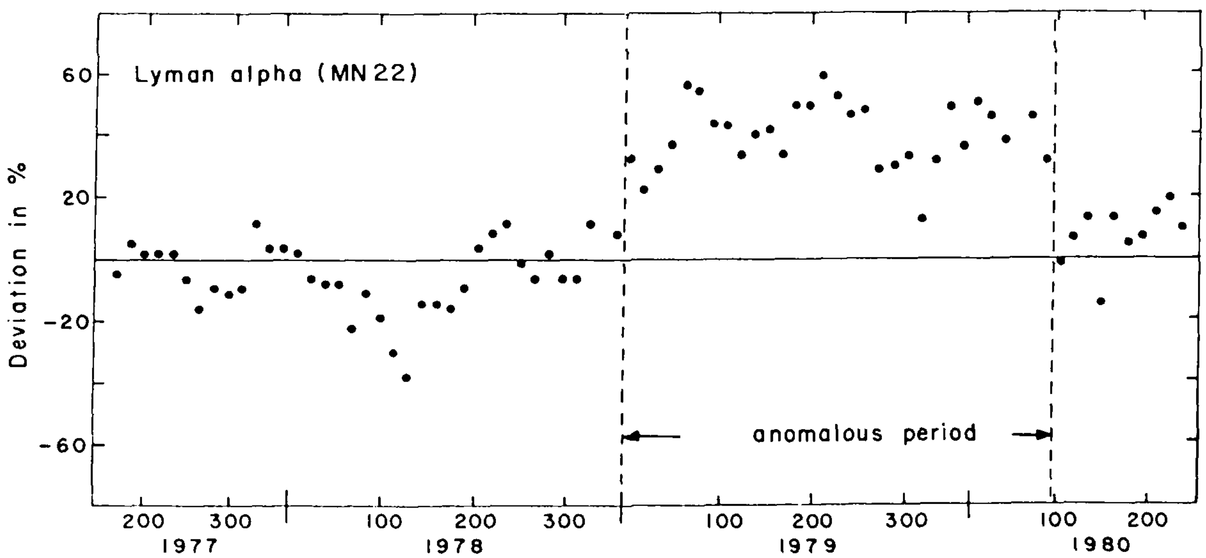

Figure 6a.

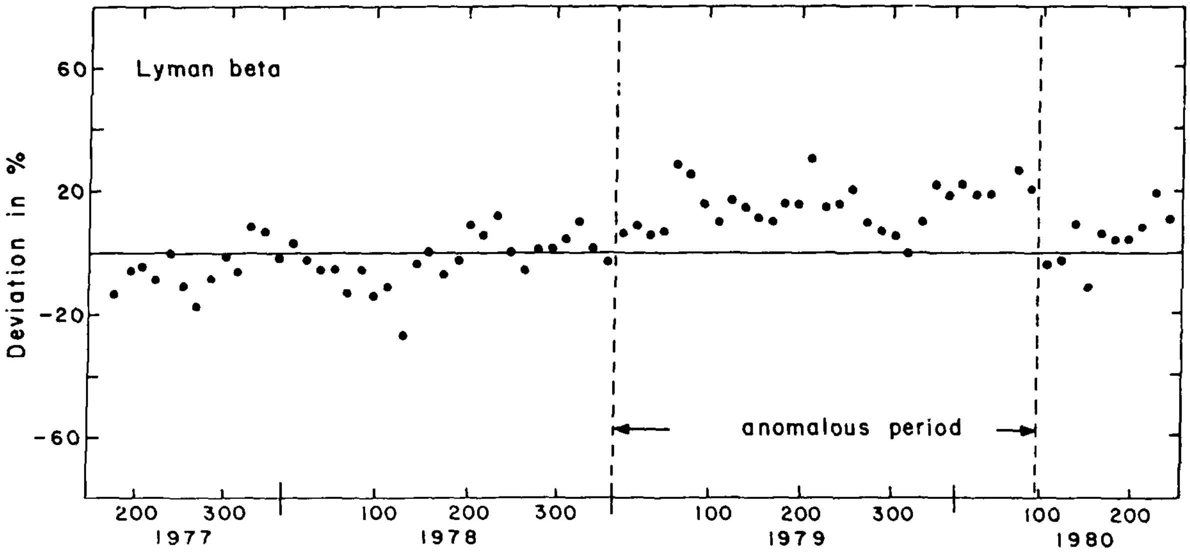

Figure 6b.

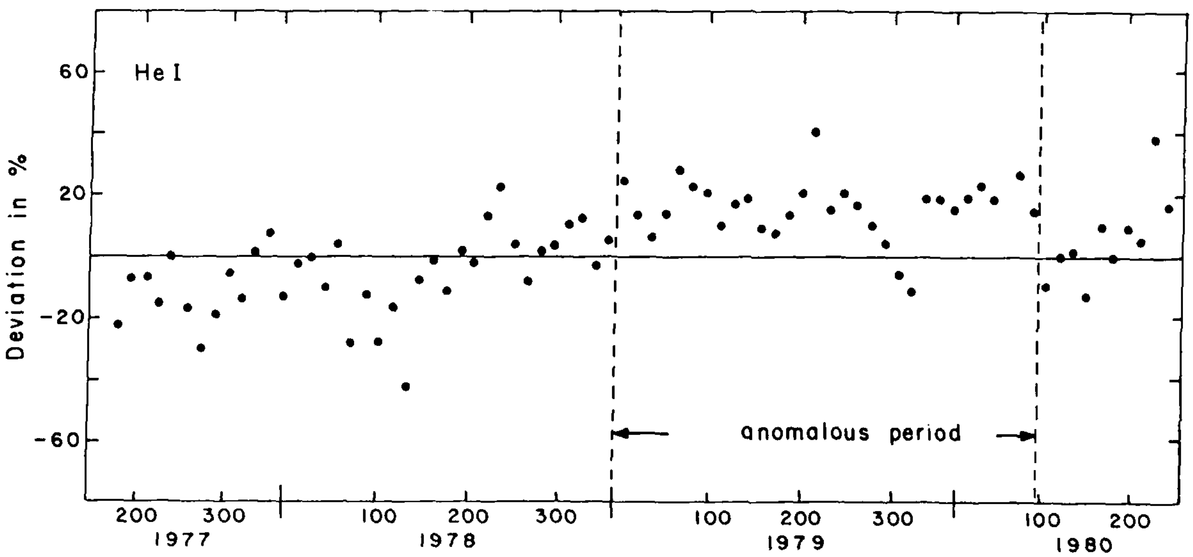

Figure 6c.

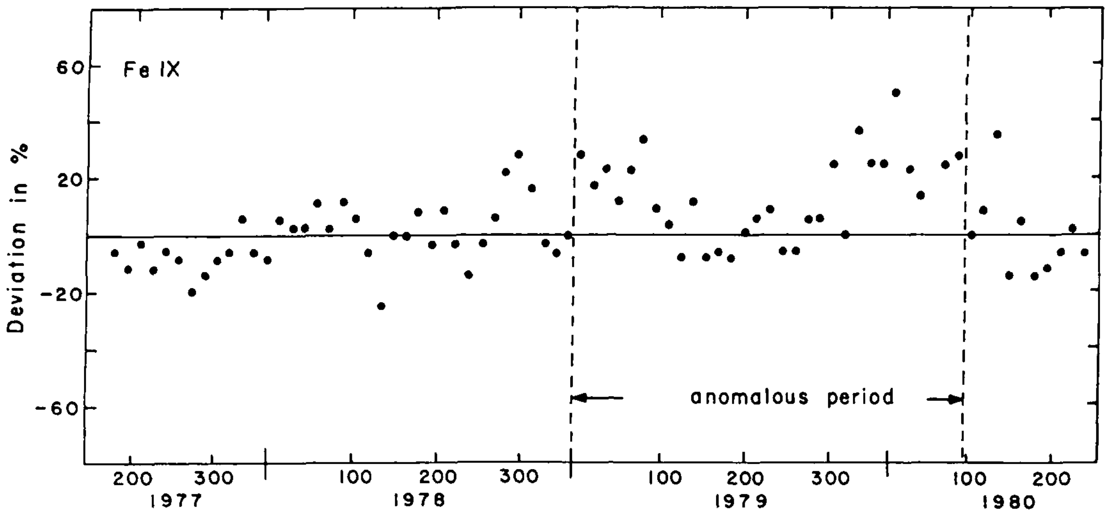

Figure 6d.

Figure 6. Excluding the Anomalous Period (79001-80094) the Relation Between the EUV Flux and F10.7 can be Approximated by a Linear Relation. Using the least square method the coefficients are calculated and any EUV flux can be estimated. The differences between the observed values and the estimated values are plotted for Lyman alpha by MN 22 (a), Lyman beta (b), HeI (c), FeIX (d). The anomalous increases are listed in Table 1. Note that as much as 41.5 percent increase is observed for the Lyman alpha flux, whereas Lyman beta, HeI, and FeIX show also substantial increases (14-16 percent) during this period indicating such an anomaly is not limited to Lyman alpha alone.

3.2 Anomalous Increase of Lyman Beta and Other EUV Fluxes

Ratios of the other EUV fluxes such as Lyman beta, HeI, and FeIX to the F10.7 values were determined, and the results were plotted in Figure 6(b), (c) and (d) respectively. The deviation of these fluxes during the anomalous period is also well observed, and they are also listed in Table 1, although the magnitudes are in the order of only about 15 percent as also given in Table 1.

As mentioned in the section on instrumentation, many EUV emission lines listed in the file SC#210BS were measured by more than one independently operated photometeric detector, either in the overlapping region or by measurement of higher order diffraction lines by different scanning monochromators. Yet there is no inconsistency between the patterns of the same emission line observed by different monochromators. Furthermore many scan-monochromators covered both coronal and chromospheric emission lines, yet produced different characteristics peculiar to each kind of emission.

Oster[5] has noticed the increase of Lyman beta and stated that not only Lyman alpha but other EUV-fluxes observed by AE-E also show some increase during the period of 79005-80047. He concluded, however, that these increases are due to the inconsistencies of the calibration which pervade the entire set of AE-E data.

3.3 Discussion of the Reliability of the Measurement

If Oster's statement has any credibility, we have to explain why only three detectors (MN 8, MN 21, and MN 22) out of 24 produced large increases with similar magnitudes at the same time.

As mentioned in the section on degradation, MN 22 and MN 8 suffered considerable degradation at the beginning, but as soon as they settled down both started producing reliable data. It is difficult to believe that after almost two years of normal operation, some incident suddenly brought back the extra higher sensitivity only for the solar maximum period when all other EUV detectors recorded also some increases.

The role of the MgF_2 filter is to cut off all the wavelengths less than 1100 Å, and not allow them to transmit. It absorbs nearly 95 percent of the incoming irradiance; thus, a small change of the crystal condition might contribute to a substantial change in the instrument response. If due to any environmental causes, filters for MN 22 and MN 8 are independently affected causing exactly the same amount of transparency change, such an anomalous increase might be observed by the two detectors independently. However, no environmental change known will reduce the opacity of the filter resulting in an increase of transmission so that the sensitivity temporarily increases and then returns to the previous level when the solar active phase ends. For example, some solar events such as energetic particles ejected during the solar active period might increase the opacity, thus resulting in degradation. Furthermore, MgF_2 filters cannot be suspected for the small rises of Lyman beta, HeI, and FeIX for the same period, since their detectors are not equipped with such filters.

MgF_2 filters were also used for MN 11 and MN 12 which were operating at the beginning of 1979 when the sudden increase of the Lyman alpha flux was observed. If a sharp change of the opacity of the filters occurred at that time, a similar drastic change should have been observed by these monochromators which were not aimed at Lyman alpha. However, no anomalous change was observed by these two (see Figure 4 by Hinteregger[7]) indicating the filters should have nothing to do with the anomalous increase.

4. CONCLUSION

This analysis indicates the EUV detectors on board the AE-E satellite measured short term as well as long term variabilities of the EUV fluxes.

The short term variabilities, especially those which are associated with the 27-day periodicity of the EUV flux including Lyman alpha, are demonstrated in the plotting published by Hinteregger[2]. They are well correlated with the variabilities of the solar indices such as F10.7. This fact also indicates that all the EUV detectors were operating normally, at least for the observation of the short term changes of fluxes.

For the observation of long-term variabilities, all the EUV fluxes seem to have nearly linear correlations with F10.7 except the period that coincides with the solar maximum phase. During this period, excess increases of the fluxes were observed for all the EUV irradiances, but it was especially large for the Lyman alpha flux, and the authenticity of this phenomenon was carefully discussed in the report.

This report is limited to presenting the result of observed data, and no physical analysis to explain the phenomenon based on the production mechanism of the EUV irradiance on the solar disk is discussed. We can only speculate that the unusually high solar activity had triggered a secondary production mechanism of the EUV fluxes in addition to the normally expected level. Probably this increase can be observed only when the solar activity reaches a certain level, perhaps Rz=120. It is not likely that the same increase would be observed again, unless the maximum phase of the solar cycle reaches the level of cycle 21.

The author realizes that the result presented in this paper is rather controversial, but if carefully carried out analysis indicates an anomalous increase, it should be considered as a possible experimental fact that is the basis of formation of new models. There is no reason to reject the result simply because it cannot be explained from the existing models.

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